UCRL-JC-120211 Abs

Thermal Analysis of the Large Close Packed Amplifiers in the National Ignition Facility (NIF)*

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Abstract

Flashlamp pumping of the large aperture multisegment NIF amplifiers will result in large amounts of energy being deposited as heat in the amplifier components. The magnitude of the heating and the nonuniform distribution result in a delay time between shots due to wavefront distortion and steering error. A NIF requirement is that the thermal wavefront recovery must occur in less than six hours. The principal cause of long-term wavefront distortion is the thermal gradient produced in the slab as heat diffuses from the edge cladding into the pumped volume. Thermal equilibrium is established through conduction, convection, and exchange of thermal radiation. Radiative exchange between glass components, such as flashlamps, blast shields, and laser slabs is especially effective because of the large surface areas of these components and the high emissivity of the glass. Free convection within the amplifier enclosure is also important but is on the order of a 10 to 20% effect compared to radiation for the major surfaces.

To evaluate the NIF design, the amplifier was modeled to calculate the thermal response of a single laser element. The amplifier is cooled by flowing room-temperature air or nitrogen through the flashlamp cassettes. Active cooling of the flashlamps and blast shields serves two purposes; 1) the energy deposited in these components can be removed before it is transferred to the amplifier optical components, and 2) the cooled blast shield provides a large area heat sink for removal of the residual heat from the laser slabs. Approximately 50 to 60% of the flashlamp energy is deposited in the flashlamps and blast shields. Thus, cooling the flashlamp cassette is a very effective method for removing a substantial fraction of the energy without disturbing the optical elements of the system. Preliminary thermal analysis indicates that active cooling with flow rates of 10 CFM per flashlamp is sufficient to meet the six hour thermal equilibrium requirement. An experiment was run with a scaled down version of the NIF laser slab to measure the thermal recovery time. This experiment was also modeled and the results from the model are compared with the thermal recovery experiment data.

*Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-ENG-48.